

## SYSTEM FOR PROTECTING A POWER SEMICONDUCTOR OUTPUT STAGE THAT SWITCHES AN INDUCTIVE LOAD

### Field Of The Invention

The present invention relates to a system for protecting a power semiconductor output stage that, as a function of a control signal, connects an inductive load to a direct-current supply voltage and disconnects it therefrom.

### Background Information

Series circuits of this kind, made up of a power semiconductor output stage and inductive load, are used for a variety of applications. The control signal always fully drives the power semiconductor output stage in order to minimize its power dissipation. When the power semiconductor output stage is disconnected, there occurs at the inductive load a disconnection energy  $W = 1/2 LI^2$  that must be kept away from the power semiconductor output stage, since by way of the latter's parasitic diode the energy would generate a current flow that could result in overload or destruction of the power semiconductor output stage. To prevent this, the load is connected in parallel with a so-called freewheeling diode, which constitutes a power diode and must be matched to the switched power of the series circuit, and is therefore very expensive.

As described in International Patent Publication No. WO 96/09683, it is also known in the context of electronically commutable motors to incorporate into the freewheeling circuit of an excitation winding the respective excitation winding that is to be energized next, and thereby already to achieve premagnetization. This system nevertheless still requires the freewheeling diode as a coupling diode between the excitation windings.

### Summary Of The Invention

It is an object of the present invention to provide a system of the kind mentioned initially that, without a freewheeling diode, protects the power semiconductor output

stage from, and dissipates, the disconnection energy  $W = 1/2 LI^2$  of the inductive load.

5 This object is achieved, according to the present invention, in that the induced voltage occurring at the inductive load upon disconnection can be transferred in transformer fashion to an additional inductance that is loaded with a resistance or is coupled in the countercurrent direction to the direct-current supply voltage.

10 Upon disconnection of the series circuit, the disconnection energy is transferred to the additional inductance, i.e. to a circuit separate from the series circuit, and dissipated through a load. By appropriate coupling of the additional inductance, the energy released can also be transferred back to the direct-current supply voltage.

Relevant inductive loads are switching relays, contactors, electronically commutable motors, and the like.

15 In the context of a switching relay and a contactor, in simple fashion the design is such that the inductive load and the additional inductance are configured as coils wound in opposite directions having a common magnetic circuit.

20 For an electronically controllable motor, the additional inductance for an energized energy winding is the oppositely energized excitation winding that is respectively next in the commutation cycle. Particularly simple circuits result if low-side-connected N-channel MOSFETs are used as power semiconductor output stages.

### 25 Brief Description Of The Drawings

Figure 1 shows a system having a switching relay switched by way of a power semiconductor output stage.

30 Figure 2 shows a system having an electronically commutable motor with four poles and two winding phases as excitation windings.

### Detailed Description

The exemplary embodiment according to Figure 1 uses an N-channel MOSFET,

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labeled T, to switch on and disconnect inductive load L. Activation is performed with a control signal  $st$  that, when present, fully drives power semiconductor output stage T so that the latter's power dissipation is minimal and the maximum current can flow through load L with load resistance  $R_L$ . In this context, practically the entire direct-current supply voltage  $U_{batt}$  drops across load L. When power semiconductor output stage T is no longer being activated because control signal  $st$  is disconnected, it then assumes the high-resistance switching state in which the parasitic diode of the power semiconductor output stage could constitute a circuit for the induced voltage of load L.

In order to greatly reduce any current flow therethrough, the induced voltage is transferred to an additional inductance  $L_z$  that is coupled in transformer fashion to load L, i.e. load L and additional inductance  $L_z$  are opposite-direction windings with a common magnetic circuit. If additional inductance  $L_z$  is loaded with a resistance R, the induction energy is thereby dissipated. The energy can also, however, as shown by the dashed lines of Figure 1, be transferred back in the countercurrent direction to direct-current supply voltage  $U_{batt}$  with smoothing capacitor C that is connected in parallel.

The circuit diagram according to Figure 2 shows, as inductive loads L1 and L2, the two excitation windings of an electronically commutable motor. Loads L1 and L2 are alternately energized in the commutation cycle; the energization direction of the excitation windings changes from step to step, since they are incorporated into the series circuits with windings in opposite directions. In the commutation cycle, power semiconductor output stages T1 and T2 are acted upon with the successive control signals  $st1$ ,  $st2$ ,  $st1$ ,  $st2$ , ... Upon energization of load L1, load L2 that is coupled in transformer fashion acts as additional inductance  $L_z$ , while upon energization of load L2, load L1 assumes the function of additional inductance  $L_z$ . In each energization phase, the circuit shown in Figure 2 operates like the circuit of Figure 1, so that here again freewheeling diodes are not necessary at loads L1 and L2 (i.e. the excitation windings of the motor), and power semiconductor output stages T1 and T2 are protected from the induced voltages occurring upon disconnection.

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